biology and life sciences forum

Cropping system and nitrogen supply interfere in sustainability of maize production in the dry season †

Karina Batista [1,*], Alessandra Aparecida Giacomini [1], Luciana Gerdes [1] and Waldssimiler Teixeira de Mattos[1]

[1] Instituto de Zootecnia – IZ, Agência Paulista de Tecnologia dos Agronegócios – APTA, 56 Heitor Penteado St. Centro, Zip Code: 13.380-011, Nova Odessa, SP, Brazil.
* Correspondence: batistakarin@gmail.com

Abstract: Diversification in cropping systems can increase production and reduce environmental impacts. Thus, we studied the maize production as function of cropping system and nitrogen rates applied as side-dressing. The experimental design was randomized blocks with four replications in a split-plot scheme. The main plots were maize monoculture; maize intercropped with Congo grass (*Urochloa ruziziensis* cv. Comum); and maize intercropped with Aruana Guinea grass (*Megathyrsus maximus* cv. Aruana). The subplots were four nitrogen rates (0; 50; 100 and 150 kg ha^{-1}) applied as side-dressing. The maize and grasses row were fertilized with nitrogen. Maize intercropped with grasses needs an adequate nitrogen supply applied as side-dressing.

Keywords: Aruana Guinea grass; Congo grass; diversification practices; environmental impacts; intercropping system; sustainable agriculture

Citation: To be added by editorial staff during production.

Academic Editor: Firstname Lastname

Published: date

1. Introduction

No-tillage is widely adopted in Brazilian farmlands, using soybean in the summer and maize (*Zea mays* L.) in the autumn-winter. However, the widespread adoption of this succession has resulted in greater uniformity of agricultural landscapes, making it less efficient and sustainable [1]. Thus, it is necessary to adopt new strategies to improve this system. Among the available strategies, the use of tropical grass intercropped with crop maize has showed environmental and economic advantages [2].

Among the species studied in the intercropping system, the genera of *Urochloa* and *Megathyrsus* showed large amounts of dry biomass, which is critical for residue formation in the no-tillage and animal feed in dry season. In addition, these grasses have high C/N and lignin/total N ratios, reducing the decomposition rate and protecting the soil against erosion and solar radiation action for a longer time [3, 4, 5]. Maize and tropical grasses are nitrogen-demanding plants, and their low availability in the soil can result in variations in their production efficiency [6]. However, there are lack of information about nitrogen supply when maize and tropical grasses are in the intercropping systems.

In this particular setting, the objective of this investigation was to assess the plant height, cob height, and grain yield of maize as function of the cropping systems and nitrogen rates applied as side-dressing.

2. Materials and Methods

A field experiment was developed from August 2019 to September 2021 in southeastern Brazil with soybean in summer and maize in autumn-winter. Here we present the results of the last maize crop (March to September 2021). The soil is a Red-Yellow Argisol - Ultisol [7,8] of medium texture. The local climate is “Aw” type [9] (Figure 1). Soil attributes before experiment are Table 1. Soil preparation was before planting in 2019.

The treatments were a split plot scheme in a randomized complete block design with four replications. The main plots were maize monoculture; maize intercropped with Aruana Guinea grass (*Megathyrsus maximum* cv. Aruana) and maize intercropped with Congo grass (*Urochloa ruziziensis* cv. Comum). The subplots were nitrogen rates 0, 50, 100, and 150 kg ha^{-1} applied as side-dressing in rows of maize and tropical grasses when the maize plants had 5–6 fully expanded leaves. There were evaluated plant height, cob height and grain yield of the maize at the time of its physiological maturity.

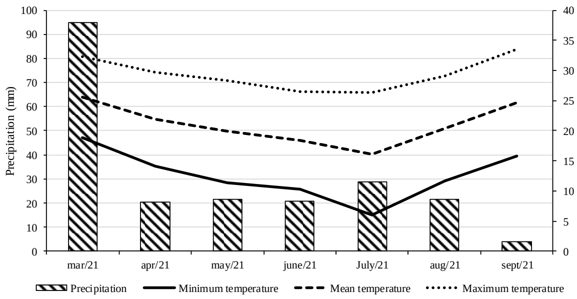

Figure 1. Temperatures and rainfall in the period.

Table 1. Soil attributes before the beginning of the experiment.

$pH_{(CaCl2)}$	O.M	$P_{(resin)}$	SO_4^{-2}	$K_{(resin)}$	$Ca_{(resin)}$	$Mg_{(resin)}$	H + Al	Al	CEC	SB
	g dm^{-3}	mg dm^{-3}		mmol$_c$ dm^{-3}					%	
4.7	30	4	9	1.5	10	7	47	3	66	28

$pH_{(CaCl_2)}$ = pH determined in CaCl2 method. O.M = organic matter determined in colorimetric method. P(resin) = phosphorus determined in resin method. SO_4^{-2} = sulfate determined in turbidimetric method. K(resin) = potassium determined in resin method. Ca(resin) = calcium determined in resin method. Mg(resin) = magnesium determined in resin method. H + Al = potential acidity determined in SMP buffer solution method. CEC = cation exchange capacity. BS = base saturation.

A sowing-fertiliser machine for a no-tillage system, with a separate box for differential distribution of large and small seeds, was used to plant maize and grasses in the same operation. The maize cultivar used was AG8061PRO2. Maize monoculture rows were spaced 0.90 m apart. In the intercropping system, the rows were spaced 0.45 m apart. Only maize rows were fertilized at planting with 30 kg ha^{-1} of N, 50 kg ha^{-1} of P_2O_5, and 40 kg ha^{-1} of K_2O [10].

The SAS GLM procedure was used for the analysis of variance. There were studied main effects and interactions. Tukey's test compared means, and regression analysis verified the effect of nitrogen rates.

3. Results

Plant height and cob height of the maize showed significance for the interaction between maize intercropped with Congo grass and nitrogen rates applied as side-dressing (Table 2). The lowest plant height (138.36 cm) in maize intercropped with Congo grass occurred at the nitrogen rate of 125.71 kg ha^{-1} (Figure 2a). Furthermore, maize intercropped with Congo grass showed lower plant height at the nitrogen rate of 100 kg ha^{-1}, differing statistically from other cropping systems (Table 2). The cob height of the maize decreased as the nitrogen rates increased in maize intercropped with Congo grass (Figure 2b). Moreover, maize intercropped with Congo grass showed lower cob height at the nitrogen rate of 100 kg ha^{-1}, not differing statistically from maize intercropped with Aruana Guinea grass (Table 2).

Table 2. Plant height, cob height and grain yield of maize at the time of its physiological maturity.

Cropping systems	N rates (kg ha-1)					F test for regression	
	0	50	100	150	Means	Linear	Quadratic
Plant height (cm)							
maize monoculture	171.50a	158.00a	182.00a	151.00a	165.63a	0.6089	0.7665
maize + Aruana Guinea grass	168.75a	151.50a	160.75a	176.00a	164.25a	0.6857	0.5881
maize + Congo grass	184.25a	176.00a	121.50b	146.00a	156.94a	0.0168	0.0327
Means	174.83	161.83	154.75	157.67		0.1575	0.2556
CV%	10.35**						
Cob Height (cm)							
maize monoculture	80.50a	72.75a	75.00a	67.25a	73.87	0.2689	0.9554
maize + Aruana Guinea grass	67.00a	62.75a	69.50ab	81.25a	70.12	0.2190	0.3193
maize + Congo grass	90.00a	85.25a	52.50b	67.50a	73.81	0.0380	0.0774
Means	79.17	73.58	65.67	72.00		0.2117	0.2406
CV%	12.63**						
Grain yield (kg ha-1)							
maize monoculture	1933.06a	1025.53b	1562.09a	602.42b	1280.77a	0.0190	0.0709
maize + Aruana Guinea grass	1106.02a	1433.14ab	1348.75ab	1899.18a	1446.77a	0.0545	0.1532
maize + Congo grass	1341.82a	1825.44a	733.39b	1138.45ab	1259.78	0.2033	0.4551
Means	1460.30	1428.04	1214.74	1213.35		0.2231	0.4781
CV%	5.55*						

Means followed by different lowercase letters in the columns differ from each other by Tukey's test at the 5% level. Coefficient of variation referring to data transformed to *log(X) and **square root (X).

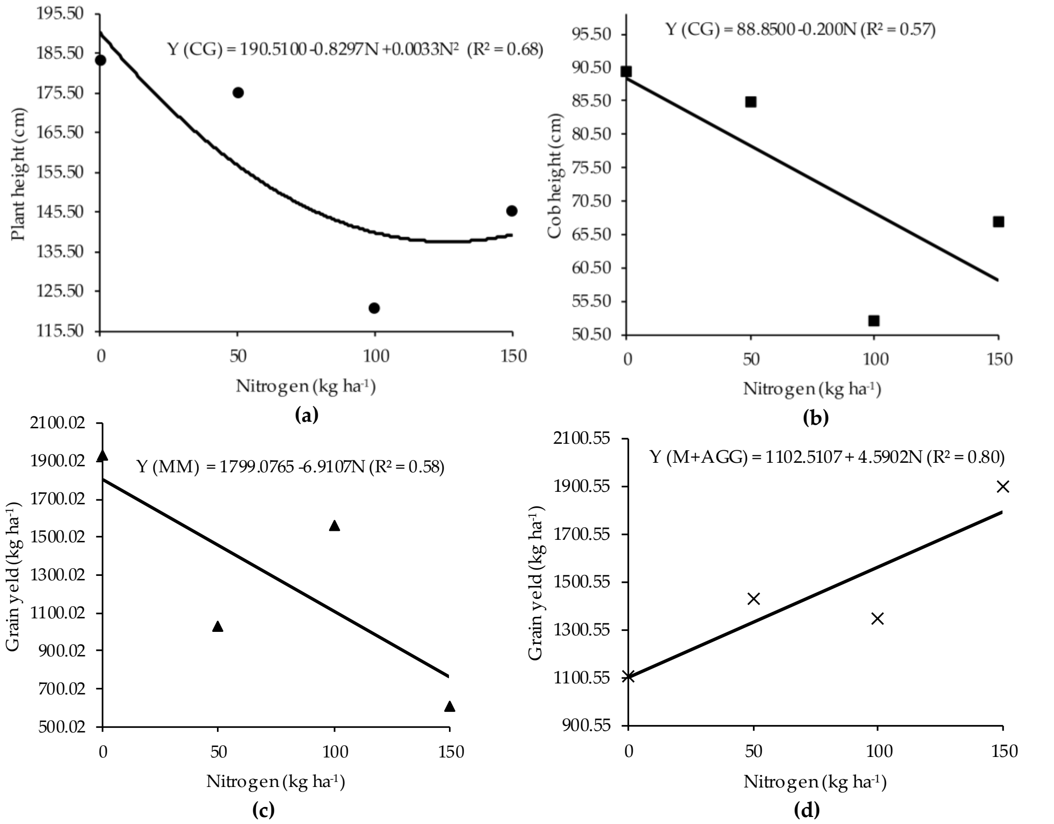

Figure 2. Plant height (a), cob height (b) and grain yield (c, d) of maize at the time of its physiological maturity as function cropping system and nitrogen rates applied as side-dressing.

The grain yield of maize showed significance for the interaction between maize monoculture and nitrogen rates applied as side-dressing, and maize intercropped with Aruana Guinea grass and nitrogen rates applied as side-dressing (Table 2). Grain yield of maize monoculture decreased linearly as the nitrogen rates applied as side-dressing increased (Figure 2c). While in the maize intercropped with Aruana Guinea grass, the grain yield increased linearly as the nitrogen rates applied as side-dressing increased (Figure 2d). In addition, no difference was observed in grain yield of maize between intercropping systems at the nitrogen rates from 50 to 150 kg ha^{-1}. Regardless of the cropping systems or nitrogen rates applied as side-dressing, the grain yield of maize was low. However, the climatic conditions in the period were unfavourable for the maize, with total precipitation from planting to physiological maturity of 185.88 mm, mean temperature of 17.79°C, and frost during grains fill of maize (Figure 1).

4. Discussion

The dynamic of the plant height and cob height showed that the adaptation of the maize intercropped with Congo grass depends on an adequate nitrogen supply (Figure 2a). Adaptation of maize height to the intercropping system is key to its agricultural performance, as increase crop uniformity, favourably split carbon and nutrients between grain and non-grain biomass, and improve efficient use of fertilizers, pesticides and water [11].

The maize showed low grain yield, which can be associated with conditions of low precipitation and temperature (Figures 1, 2c and 2d). The impact of the climate variables on crop yield can be summarized as follows: rainfall is related to crops yield, affecting the water balance, since when soil water limits the ability of crops to meet atmospheric demand of evaporation, the stomata close, reducing water loss, but also photosynthesis. While extremely low or high temperatures damage the vegetative and reproductive structures of the plant [12]. In addition, the moisture conditions of the dry soil after the six fully expanded leaf stage, a period that corresponded to maize development after nitrogen fertilization as side-dressing, may limit maize root development, nitrogen uptake and biomass production above soil, thus reducing the number and mass of the maize grain [13].

The grain yield (Figures 2c and 2d) also illustrated the challenges associated with the application of nitrogen in the maize intercropped with tropical grasses in the dry season. Drought conditions, during the late vegetative growth period and the onset of stigma-style, represents a critical period when soil moisture or nutrient deficiency can reduce the maize grain yield potential [14].

5. Conclusions

Our results showed when maize is intercropped with Congo nitrogen supply interfered in plant height and cob height. In conditions, high nitrogen supply occurred low cob height. When maize is intercropped with Congo grass is necessary high nitrogen supply for high grain yield. Maize intercropped with tropical grasses is more nitrogen-demanding than maize monoculture.

Author Contributions: Conceptualization, K.B.; methodology, K.B; formal analysis, K.B.; investigation, K.B., A.A.G., L,G. and W.T.M.; resources, K.B.; data curation, K.B.; writing—original draft preparation, K.B.; writing—review and editing, K.B.; visualization, K.B.; supervision, K.B.; project administration, K.B.; funding acquisition, K.B. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the São Paulo Research Foundation—FAPESP (process 2017/50339-5 and process 2019/02387-6).

Data Availability Statement: The data that support this study are available in the article.

Acknowledgments: The authors are grateful to FAPESP (São Paulo State Research Support Foundation) for providing financial support.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Hufnagel, J.; Reckling, M.; Ewert, F. Diverse approaches to crop diversification in agricultural research. A review. *Agron. Sustain. Dev.* **2020**, 40, 1-17. doi: 10.1007/s13593-020-00617-4

2. Garbelini, L.G.; Franchini, J.C.; Debiasi, H.; Balbinot Junior, A.A.; Betioli Junior, E.; Telles, T.S. (2020) Profitability of soybean production models with diversified crops in the autumn–winter. *J. Agron.* **2020**, 112, 4092–4103. doi: 10.1002/agj2.20308
3. Batista, K.; Duarte, A.P.; Ceccon, G.; De Maria, I.C.; Cantarella, H. Acúmulo de matéria seca e de nutrientes em forrageiras consorciadas com maize em função da adubação nitrogenada. *Pesqui. Agropecu. Bras.* **2011**, 46, 1154-1160. doi:10.1590/S0100-204X2011001000006
4. Pereira, F.C.B.L.; Mello, L.M.M.; Pariz, C.M.; Mendonça, V.Z.; Yano, E.H.; Miranda, E.E.V.; Crusciol, C.A.C. Autumn maize intercropped with tropical grasss: crop residues, nutrient cycling, subsequent soybean and soil quality. *Rev. Bras. Cienc. Solo* **2016**, 40, 1-20. doi: 10.1590/18069657rbcs20150003
5. Sapucay, M.J.L.C; Coelho, A.E.; Bratti, F.; Locatelli, J.L.; Alvadi, L.S.; Balbinot Junior, A.; Zucareli, C. Nitrogen rates on the agronomic performance of second-crop maize single and intercropped with ruzigrass or showy rattlebox. *Pesqui. Agropecu. Trop.* **2020**, 50, e65525. DOI: 10.1590/1983-40632020v5065525
6. Batista, K.; Giacomini, A.A.; Gerdes, L.; Mattos, W.T.; Otsuk, I.P. Impacts of the nitrogen application on productivity and nutrients concentrations of the maize-Congo grass intercropping system in the dry season. *Acta Agric. Scand. - B Soil Plant Sci.* **2019**, 69, 567-577. doi: 10.1080/09064710.2019.1617345
7. Santos, H.G.; Jacomine, P.K.T.; Anjos, L.H.C.; Oliveira, V.A.; Lumbreras, J.F.; Coelho, M.R.; Almeida, J.A.; Araújo Filho, J.C.; Oliveira, J.B.; Cunha, T.J.F. *Sistema brasileiro de classificação de solos*, 5th ed.; Embrapa: Brasília, Brazil, 2018; 356p.
8. United States Department of Agriculture. *Keys to soil taxonomy*, 12th ed.; United States Department of Agriculture; Natural Resources Conservation Service: Washington, WA, USA, 2014; 359p.
9. Alvares, C.A.; Stape, J.L.; Sentelhas, P.C.; Gonçalves, J.L.M.; Sparovek, G. Köppen's climate classification map for Brazil. *Meteorol. Z.* **2013**, 22, 11–728. DOI: 10.1127/0941-2948/2013/0507.
10. Van Raij, B.; Cantarela, H.; Quaggio, J.A.; Furlani, A.M.C. *Recomendações de Adubação e Calagem Para o Estado de São Paulo*, 2nd ed.; Instituto Agronômico e Fundação IAC: Campinas, Brazil, 1997; 285p.
11. Peiffer, J.A.; Romay, M.C.; Gore, M.A.; Flint-Garcia, S.A.; Zhang, Z.; Millard, M.J.; Gardner, C.A.C.; Mcmullen, M.D.; Holland, J.B.; Bradbury, P.J.; Buckler, E.S. The genetic architecture of maize height. *Genetics* **2014**, 196, 1337–1356. doi: 10.1534/genetics.113.159152
12. Hoffman, A.L.; Kemanian, A.R.; Forest, C.E. The response of maize, sorghum, and soybean yield to growing-phase climate revealed with machine learning. *Environ. Res. Lett.* **2020**, 15, 1-20. doi: 10.1088/1748-9326/ab7b22
13. Spackman, J.A.; Fernandez, F.G.; Coulter, J.A.; Kaiser, D.E.; Paiao, G. Soil texture and precipitation influence optimal time of nitrogen fertilization for maize. *J. Agron.* **2019**, 111, 2018-2030. doi:10.2134/agronj2018.09.0605
14. Iseghohi, I.; Abe, A.; Meseka, S.; Mengesha, W.; Gedil, M.; Menkir, A. Effects of drought stress on grain yield, agronomic performance, and heterosis of marker-based improved provitamin-A maize synthetics and their hybrids. *J. Crop Improv.* **2021**, 35, 1–21. doi:10.1080/15427528.2021.194977